TECHNICAL STUDY #29

HARDENING — OPTIMUM BLAST PROTECTION FOR MINIMUM COST

By

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INTRODUCTION

The rapid development of thermonuclear weapons has accentuated the need to improve our knowledge of measures which can be taken to minimize the effects of an attack. Similarly, the continuous improvement in our state of knowledge regarding protective measures imposes upon our military commanders, a requirement for continued revision of our thinking and reappraisal of our planning relative to minimizing the effects of nuclear attack on our nation. One of our major goals should be to provide at a cost we can afford, means of assuring a reasonable probability of survival for our retaliatory capability by choosing a realistic combination of mobility, dispersal, and hardening.

Obviously there is no single answer to the problem of improving survivability. The method or methods to be utilized will depend on the situation under consideration and the assumptions made. The relative advantages of each method or combination of methods and the relative costs of various alternatives should be considered prior to implementing the design phase.

Air blast (with associated induced ground motions) produced by nuclear explosions is probably the most important single parameter to be considered in the design of relatively shallow buried cut-and-cover type of protective construction. This is particularly true in the high overpressure regions because the blast loading on the structure, the blast doors and the blast closure devices will be strongly dependent upon the magnitude of the peak overpressure assumed for design. The duration of the positive phase of the blast wave will also be important for some considerations but will not in general be an overriding design consideration for pressure pulses produced by modern large yield weapons.

Generally the choice of a design overpressure should involve a concientious realistic balancing of a number of variables. A few of these variables will be: assumed weapon size and associated delivery errors; location relative to a potential target area; relative importance of the facility, i.e., whether or not the facility is a target; the amount of money which can be afforded for protection; the nature of the facility; the time available for completion, etc..

Obviously, the strength designed into the structure and its appurtenances will have to be sufficient to withstand the loading forces induced by the assumed blast wave. Since these forces can generally be related to the peak overpressure of the blast wave (particularly for large yield weapons) it is apparent that the cost of the structural aspects of

the facility will be largely dependent upon the magnitude of the design overpressure. Accordingly, it appears wise to attempt to develop one or more means of assisting the planners in the choice of a realistic design overpressure for a facility under consideration. Perhaps the easiest but least satisfactory method of choosing such a design overpressure is by arbitrary choice or by command decision. It is believed that the role of command decision should be limited to selection of an acceptable survival probability for a specified attack condition.

The purpose of this paper is to present a method of assisting in the choice of a design overpressure which would give the maximum survival probability per unit cost. The method as presented in this paper is applicable to various types of relatively shallow buried cut-and-cover structures subjected to potential air blast damage by direct attack with nuclear weapons. For the curves presented later, it is assumed that the facility is the aiming point. The method is admittedly crude but will provide an additional means of reviewing proposed protective construction. The major limitation of the method is lack of specific well defined cost factors over the wide range of overpressures considered. It is expected that minor modifications of the method will apply to other protected facilities of any nature regardless of whether they are considered prime targets or near prime targets.

Relatively simple means are available for analysis of the survival probability of a facility which is near an assumed target but is not itself a target. For example, reference 1 may be used for this analysis.

THE METHOD

The basic inputs to the proposed method are: Estimated cost or relative cost of protected structures as a function of airblast peak overpressure on the ground surface used in the design; the assumed yield of the attack weapon and the assumed delivery errors expressed in circular error probable (CEP) of the weapon delivery system.

The cost estimates used in this study are based on a study of typical cost factors (Reference 2) obtained by taking composite averages of costs of various protective structural types compared with the cost of conventional above-ground construction. Figure 1 is an extrapolation of the cost factor vs. overpressure curve for below-ground structures.

By a series of relatively simple computations, as outlined in references 1 and 3, a family of curves showing the relationship between the ratio of relative cost to survival probability and the design overpressure have been derived. Each curve in this family (the fine lines in Figure 2) represents a specific assumed weapon size and delivery error expressed in terms of CEP. The interesting feature of the curves is that each has a minimum point at a specific design overpressure and the locus of these minima can be represented by a single curve (the heavy line) as

shown in Figure 2. The reason for the minima is that in moving to the left of this curve, the survival probability will decrease more rapidly than the cost whereas to the right of the curve the cost is increasing at a more rapid rate than the survival probability.

The significance of the heavy curve is that it will permit at a glance, the selection of a design overpressure which will give the maximum survival probability per unit cost for each assumed weapon size and delivery error. Any proposed selection which will fall to the left or above the curve should probably be reconsidered since merely increasing the design overpressure to a point on the curve will increase the survival probability. However, in doing this it must be recognized that any higher overpressure chosen for design purposes will cost more. However, the increase in cost should be weighed against the potential benefits to be gained by the increased survivability. In the high overpressure region the major problem areas are severe motions, and blast closures for entrances and ventilation systems rather than structural strength. Therefore, for certain types of cut-and-cover structures, even a few hundred psi may be too high.

Any design overpressure selection to the right of the curve (for the assumed weapon size and delivery error) should be considered with the full recognition that a premium cost must be paid for a relatively small increase in survival probability. It is possible that the additional premium cost will be required to obtain an acceptable survivability but it should not be decided arbitrarily without investigating the relative merits of other means of increasing the survivability.

Another interesting feature of the curve is that the overpressure protection required to optimize survivability vs. cost gets excessively high as the weapon size increases into the Megaton range and the delivery errors decrease to small numbers. Under these assumptions, duplication, dispersal and/or mobility may be required with or without hardening in order to obtain an acceptable survival probability.

Additional insight on the relationship between cost, survival probability, weapon size and CEP can be obtained by referring to Figure 3. The significance of these curves is that for the various delivery errors, there is an appreciable range of weapon size where the slope of the curves are relatively small. Significantly, the slope does not break sharply upward until weapon yields in the large KT sizes are assumed for the small CEP's (accurate delivery) and until MT size weapons are assumed for the larger CEP's. The design overpressures corresponding with relative cost to survival probability ratios of 10 to 20 will be approximately 200 to 300 psi., respectively.

In order to permit additional utilization of Figure 2, additional information is required in order to relate design overpressure to survival probability. Figures 4-6 present the probabilities of survival vs. design overpressure for three weapon sizes with CEP's varying from 1,000 feet to 1 statute mile.

The following is an example of the use of this method. The first step is to assume an attack weapon size and CEP. For this example 1 MT with a 3,000 foot CEP is assumed. By reference to Figure 2 a tentative selection of an optimized design overpressure can be made—this would be approximately 150 psi. By referring to the appropriate curve in Figure 4 it can be seen that the survival probability will be 55% for the assumed conditions.

SUMMARY

A method is presented ~~which~~ under assumed conditions, it is possible to select with ease, a design overpressure for a hardened facility which will give the maximum survival probability per unit cost. It should not be used as a rigid criteria but rather as a guidance in the early phases of planning protective construction.

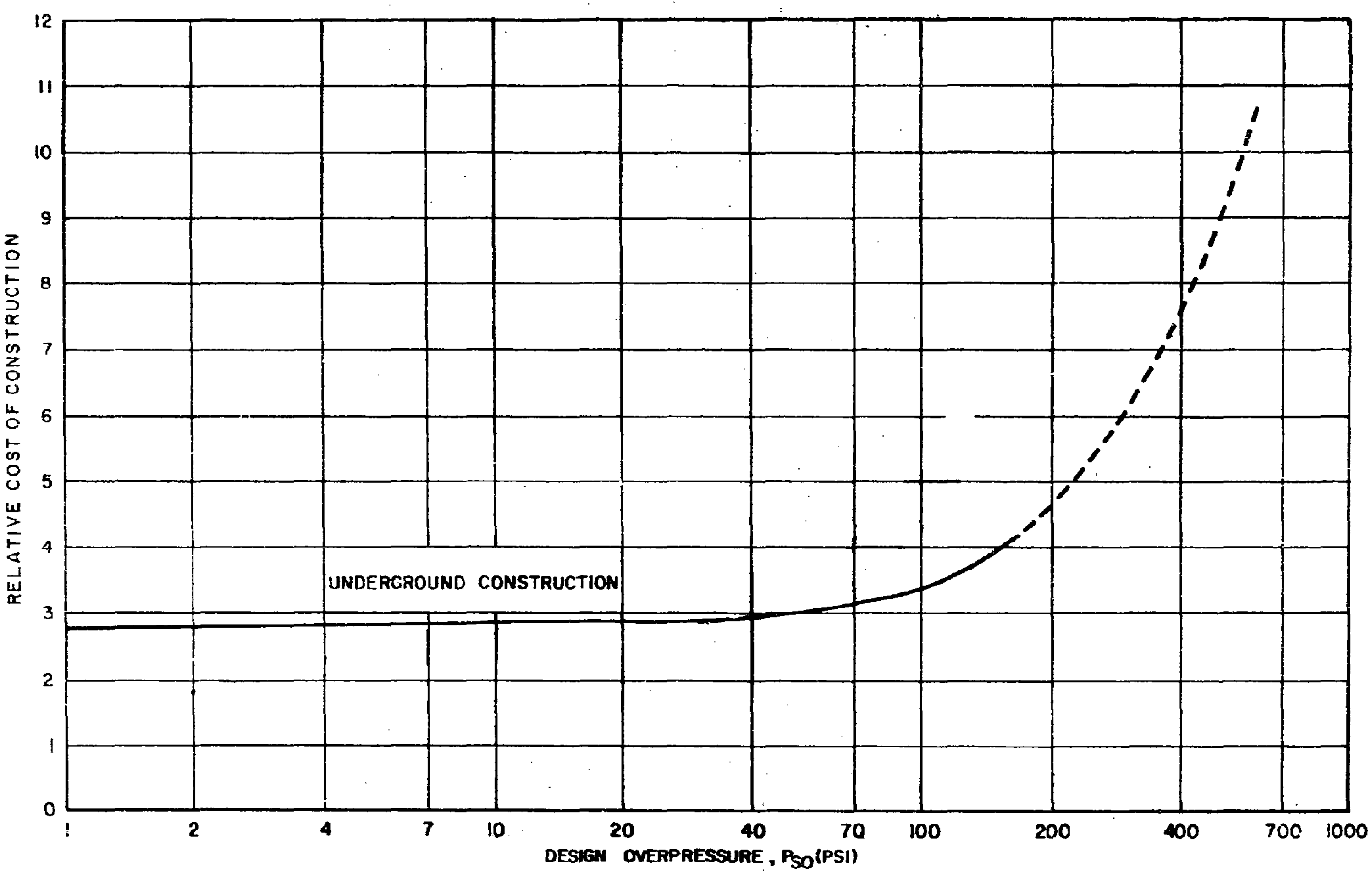
REFERENCES

1. Field Command, Defense Atomic Support Agency, "Atomic Weapons Employment", WE-M-3, 13 March 1959.

2. DOD Protective Construction Review Guide, Vol. I (Hardening), June 1961.

3. Bureau of Yards and Docks Technical Study #28, "Relative Vulnerability of Underground Protective Construction", September 1959.

4. Defense Atomic Support Agency, "Capabilities of Atomic Weapons", OPNAVINST 03400.1B, November 1957.



RELATIVE COST OF CONSTRUCTION VS DESIGN OVERPRESSURE
(CUT AND COVER IN DRY SOIL)

Figure I

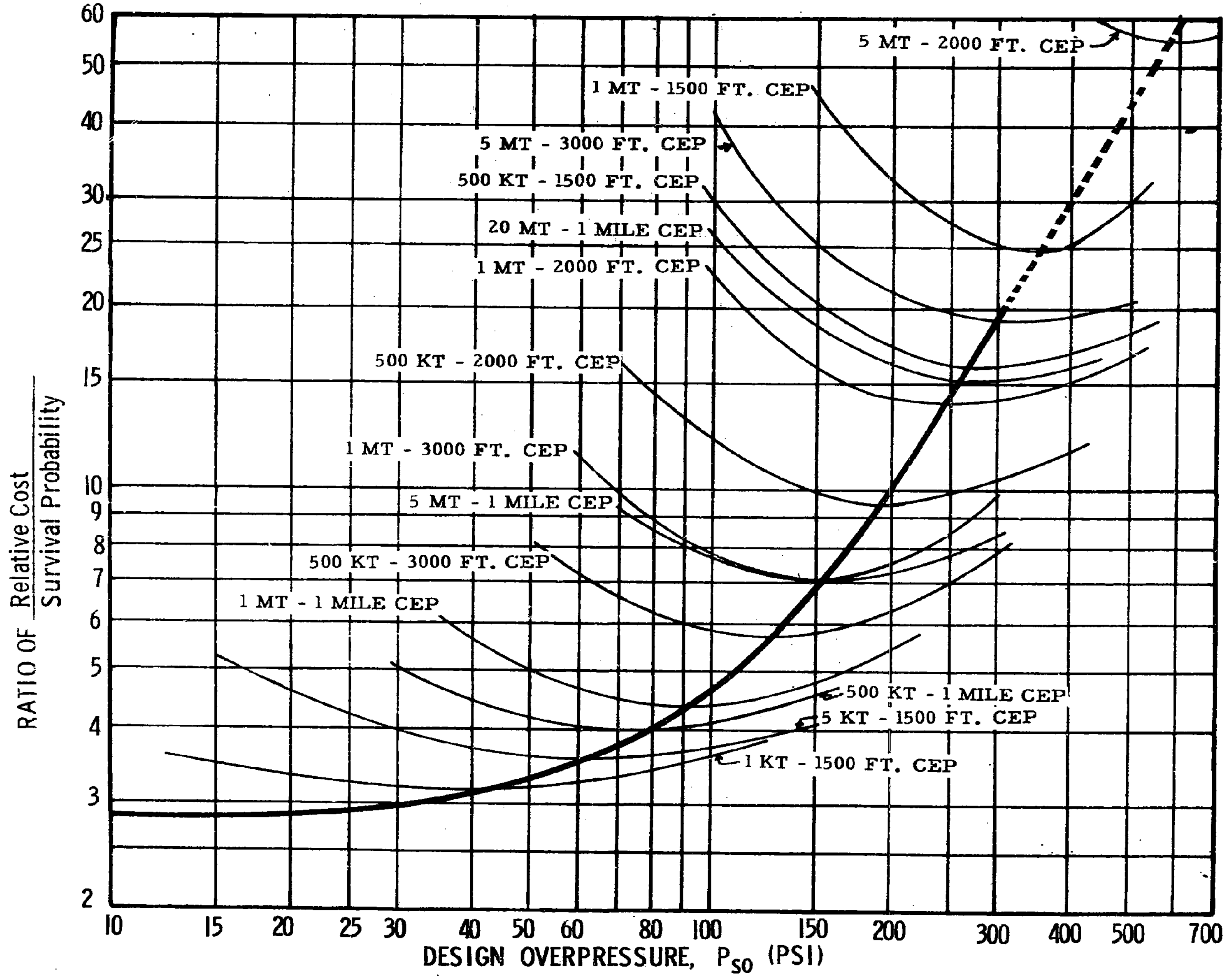

5 MT - 2000 FT. CEP
1 MT - 1500 FT. CEP
5 MT - 3000 FT. CEP
500 KT - 1500 FT. CEP
20 MT - 1 MILE CEP
1 MT - 2000 FT. CEP
500 KT - 2000 FT. CEP
1 MT - 3000 FT. CEP
5 MT - 1 MILE CEP
500 KT - 3000 FT. CEP
1 MT - 1 MILE CEP
500 KT - 1 MILE CEP
5 KT - 1500 FT. CEP
1 KT - 1500 FT. CEP
60
50
40
30
25
20
15
10
9
8
7
6
5
4
3
2
RATIO OF Relative Cost / Survival Probability
10
15
20
25
30
40
50
60
80
100
150
200
300
400
500
700
DESIGN OVERPRESSURE, P_{SO} (PSI)

Figure 2

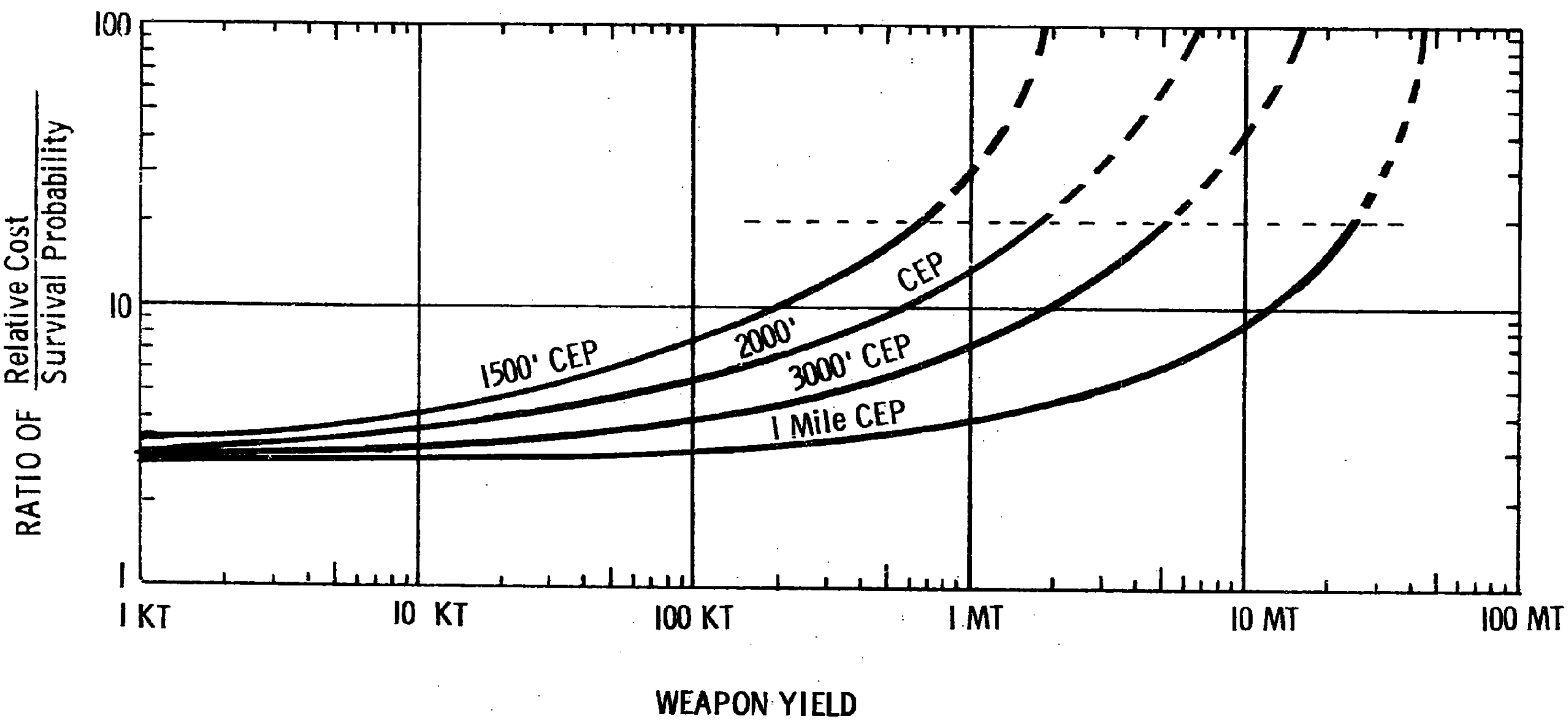
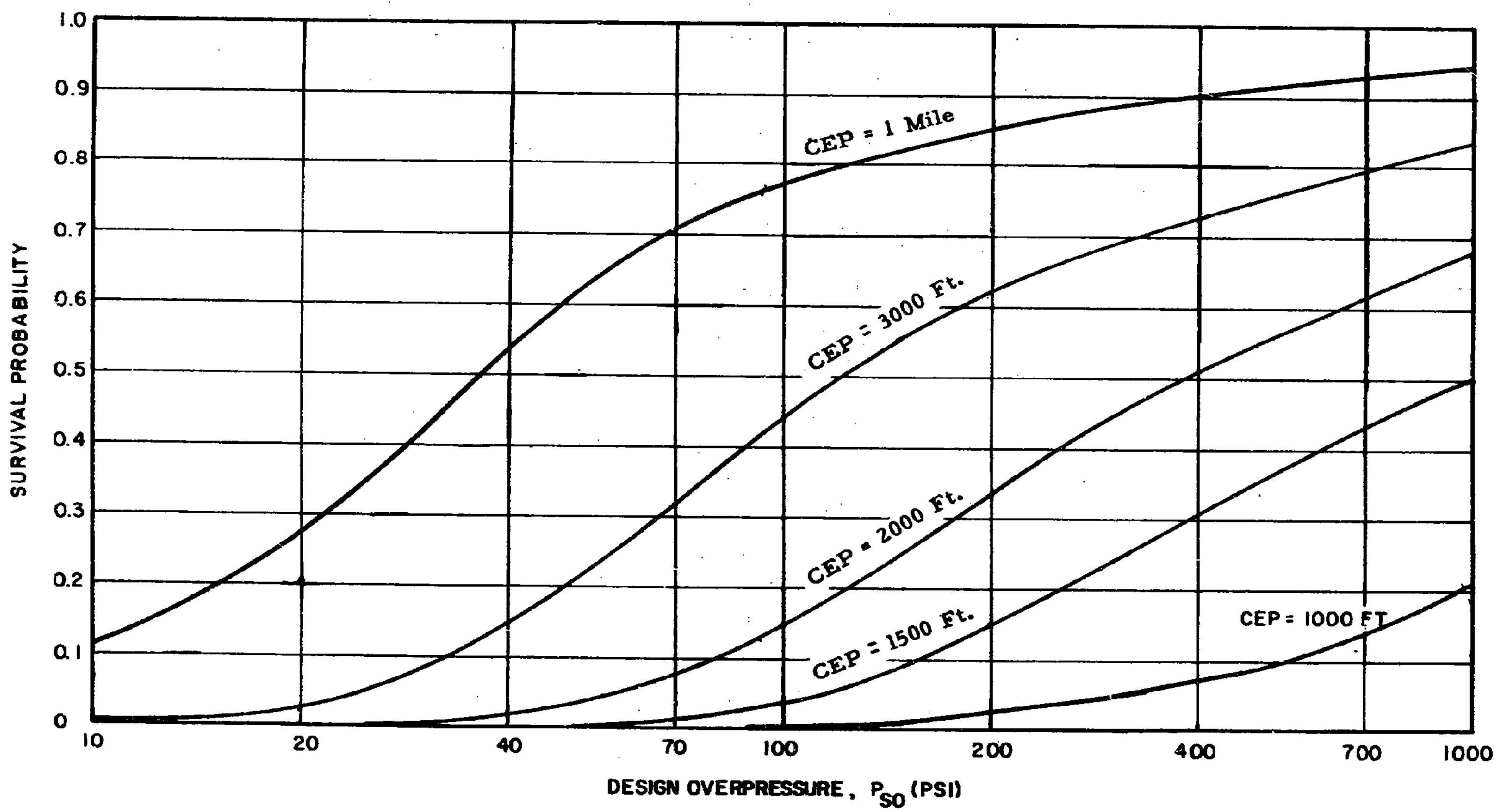
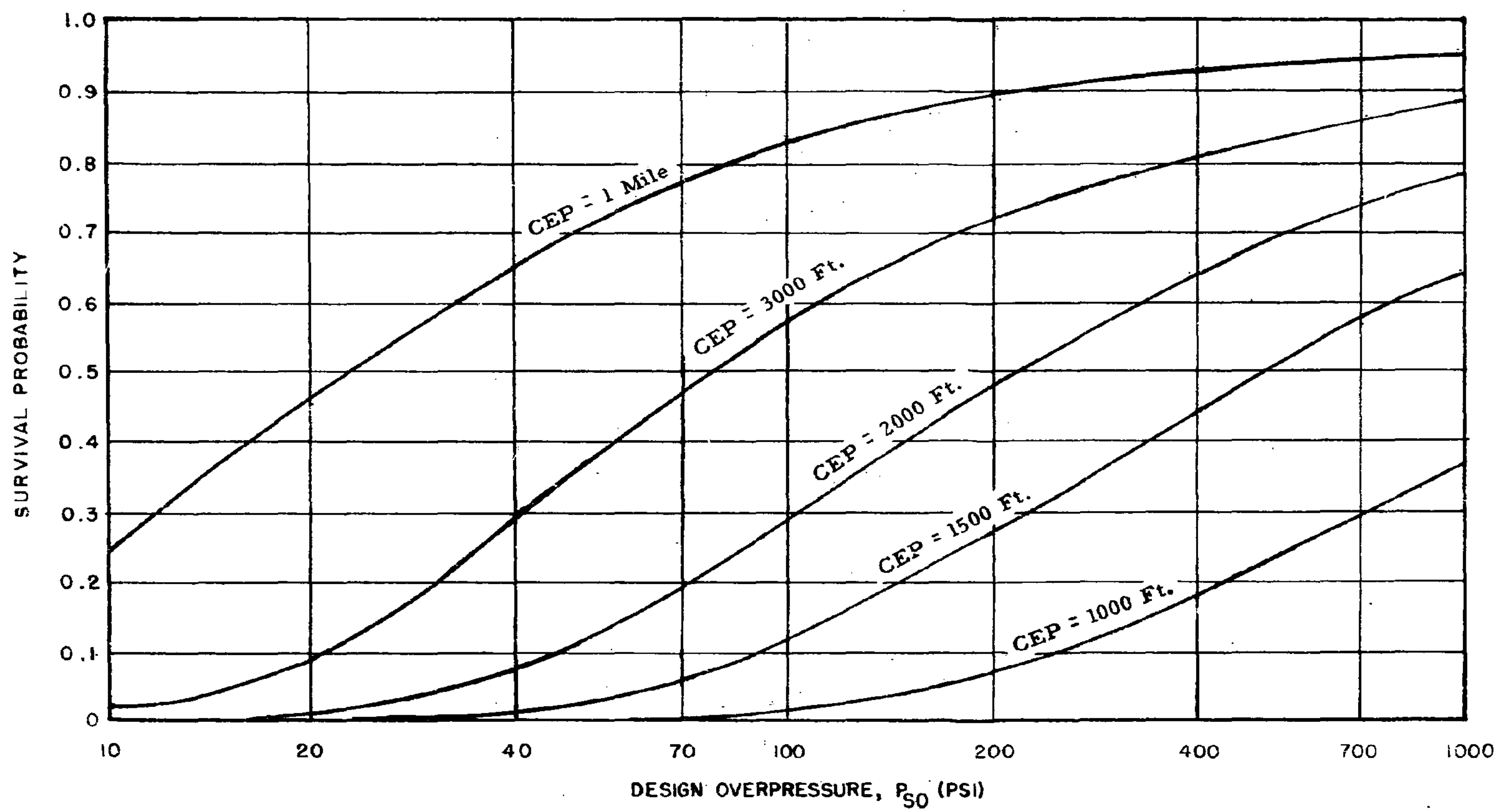

RATIO OF Relative Cost / Survival Probability
100
10
1
1 KT
10 KT
100 KT
1 MT
10 MT
100 MT
1500' CEP
2000' CEP
3000' CEP
1 Mile CEP
WEAPON YIELD

Figure 3



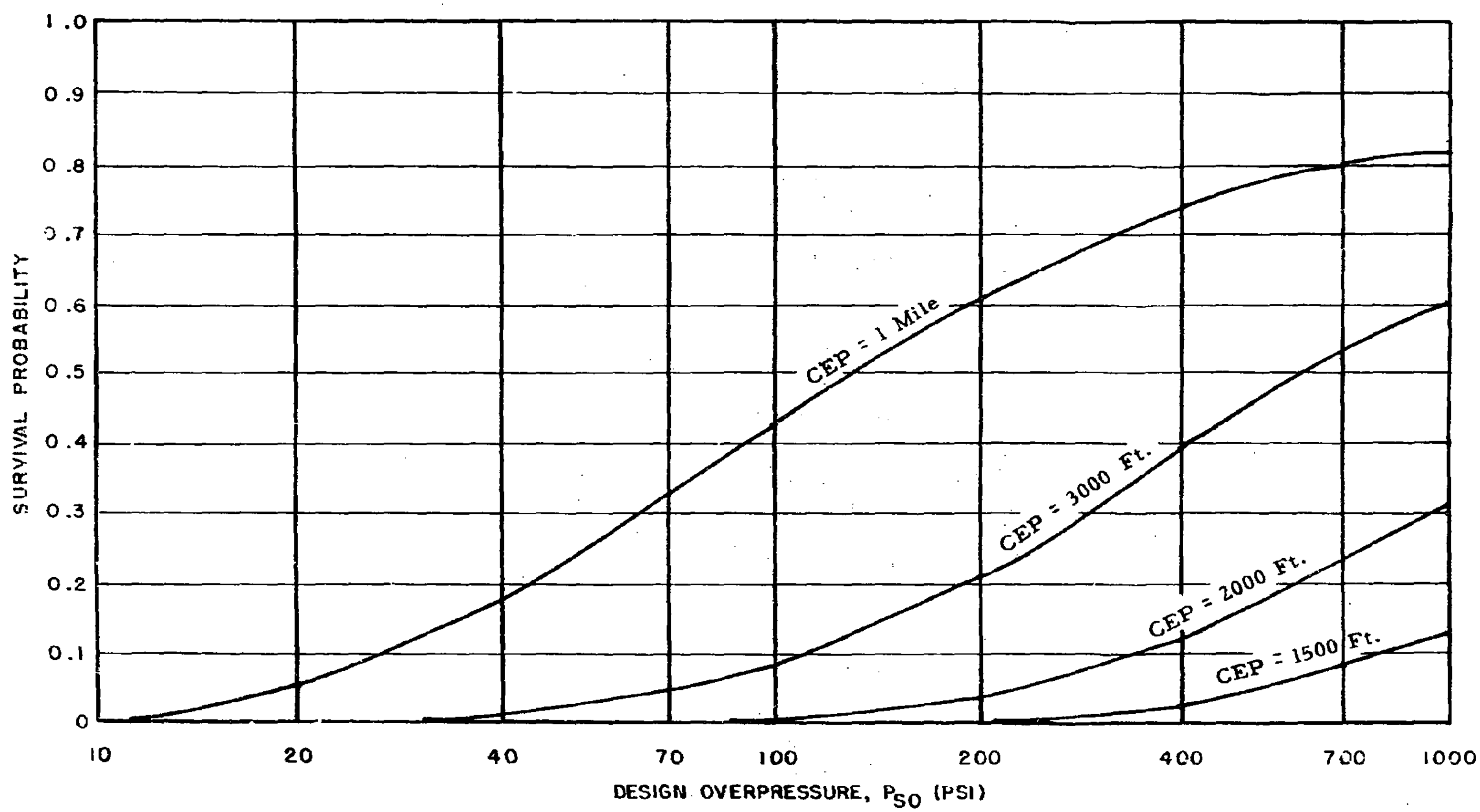
PROBABILITY OF SURVIVAL FROM AIR BLAST VS DESIGN OVERPRESSURE FOR A 1 MT EXPLOSION

FIGURE 4



PROBABILITY OF SURVIVAL FROM AIR BLAST VS DESIGN OVERPRESSURE FOR A 500 KT EXPLOSION

FIGURE 5



PROBABILITY OF SURVIVAL FROM AIR BLAST VS DESIGN OVERPRESSURE FOR A 5 MT EXPLOSION

FIGURE 6